Longevity and Lifetime Labor Supply: Evidence and Implications Revisited*

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First version: July 2009
This version: March 2010

Abstract

Hazan (2009) presents a model predicting that an increase in expected total lifetime work hours is a necessary condition for greater longevity to induce more schooling. The observation of a continued reduction of expected total work hours leads Hazan (2009) to conclude that longevity improvements cannot explain the observed increases in schooling in the U.S. over the past 150 years. This conclusion questions the relevance of the link between mortality decline and investment in human capital.

This paper generalizes Hazan's (2009) theoretical analysis and shows that, in general, the necessary condition for a reduction in mortality rates to induce more years of schooling is that the increase in longevity is associated with an increase in the benefits of schooling *relative* to the opportunity costs of a delayed entry into the labor market. An increase in expected total work hours is only a necessary condition under specific and counterfactual assumptions. When replicating the empirical analysis, we find no evidence that greater longevity has been associated with a decline in the relative benefits of schooling. The results do not confirm Hazan's conclusion that increased longevity cannot have led to larger education attainments.

JEL-classification: E20, J22, J24, J26, O11.

Keywords: Longevity, Human Capital, Lifetime Labor Supply, Survival Probability, Rectangularization

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1 Introduction

In a recent article, Hazan (2009) claims that an increase in expected lifetime labor supply constitutes a necessary condition for an increase in longevity to induce more investment in schooling. The article then presents evidence of a sizable reduction in expected total working hours for U.S. workers born in the period 1840-1970. Hazan interprets this evidence as pointing to a violation of the necessary condition and concludes that the reduction in mortality rates in the U.S. during this period cannot account for any of the increase in education attainment. This conclusion has very important implications for policy, since it challenges the view that reducing mortality and improving health may promote the acquisition of human capital, as well as for academic research, since it questions the empirical relevance of studying the link between mortality and human capital.

This paper revisits the theoretical and empirical analysis of Hazan (2009). Section 2 generalizes the model and shows that the theoretical predictions are not robust. The optimal choice of (years of) schooling requires that marginal benefits from delaying the entry in the labor market equals marginal costs. The marginal benefits are given by the increase in the level of human capital obtained by staying at school longer, which pays off for the remaining expected work life. The marginal (opportunity) costs are given by the income that is forgone when staying at school longer rather than entering work life. In general, the necessary (and sufficient) condition for longevity to increase schooling is to induce an increase in its marginal benefits *relative* to its opportunity costs, and not an increase in expected total hours of work.

The analysis in Hazan (2009) is developed under the assumption of a perfectly rectangular survival probability and a linear human capital production function. Individuals are assumed to survive with probability one during all their life, and die with probability one when reaching their life expectancy. In this setting, mortality can affect the education decision only by extending the maximum longevity, but not by changing the probability of surviving during working ages. However, this assumption is strongly counterfactual and hides the effect of the observed changes in age-specific mortality rates on the costs and benefits of education. In more general settings, changes in mortality rates affect both the costs and benefits of schooling. This is true for most theoretical frameworks that study endogenous schooling in the context of changing mortality, including de la Croix and Licandro (1999), Boucekkine, de la Croix and Licandro (2002, 2003), Soares (2005), and Cervellati and Sunde (2005), which, contrary to the conjecture made by Hazan (2009, p. 1830-31), do not share his specific predictions.

The theoretical analysis has an immediate empirical implication: the observation of a reduction in expected total hours of work does not allow for the conclusion that reductions in mortality cannot have induced any of the observed increase in schooling in the U.S. over the last 150 years. Section 3 replicates the empirical analysis by Hazan (2009) using his data for the cohorts born 1840-1930. It is shown that the increase in life expectancy at birth was mainly the result of a progressive increase in survival probabilities during working ages rather than of an increase in maximum lifetime horizon. Furthermore, the drop in mortality rates during working ages was associated with pronounced changes in labor supply and schooling intensity across cohorts. This materialized in a marked increase in the expected years of active work, despite a tendency towards earlier retirement from the labor force. The data show a more than proportional reduction of hours of work at young ages compared to prime ages implying that the opportunity costs for more schooling and delaying the entry into the labor market decreased. Consistently, the relative marginal benefits from schooling display an increase, especially after 1870. The results indicate that there is no obvious violation of the necessary condition for reductions in mortality to have led to an increase in schooling. The conclusion that changes in life expectancy "cannot account for any of the immense increase in educational attainment over the last 150 years" (Hazan, 2009 p. 1857) is therefore not supported in the data when considering a more general framework.

This paper is structured as follows. We revisit the theoretical and empirical analysis in Section 2 and Section 3, respectively. Section 4 discusses the implications of other simplifying assumptions, and Section 5 concludes.

2 Theoretical Predictions Revisited

2.1 Model Set-Up

Consider the framework studied in Hazan (2009) but generalized for a generic, non rectangular, survival law. Set birth at $t = 0$ so that t also represents the age of individuals. Denote by $p(t) \in [0, 1]$ the unconditional probability of being alive at age t, and by $P(t)$ the corresponding cumulative distribution function. The maximum age that can be reached is $\overline{T} \in (0, \infty)$, implicitly defined by $P(\overline{T}) = 0$, while life expectancy at birth is denoted by T.

At each age t, individuals derive utility from consumption, $u(c(t))$, where the utility function $u(\cdot)$ is assumed to be twice continuously differentiable and concave. With a discount rate ρ, the individual's expected lifetime utility is given by,

$$V = \int_0^{\overline{T}} e^{-\rho t} p(t) u(c(t)) dt \, . \tag{1}$$

At each age t individuals can either study or work but not both. Denote by S the number of periods devoted to school, and by $R \leq \overline{T}$ the retirement age.[1] Total lifetime consumption is financed by total lifetime labor earnings. Denote by $e^{\theta(S)}$ the labor earnings associated with the supply of one unit of labor for an individual that has spent S periods in school. The function $\theta(\cdot)$ is increasing and weakly concave. There are perfect capital markets with exogenous interest rate r so that, analogously to equation (1) in Hazan (2009), the individual lifetime budget is given by,

$$\int_S^R e^{-rt} p(t) e^{\theta(S)} dt = \int_0^{\overline{T}} e^{-rt} p(t) c(t) dt. \tag{2}$$

2.2 Optimal Schooling

Individuals have to decide optimally on the length of schooling, S. The main trade-off in acquiring human capital is between sacrificing current earnings in order to increase human capital, and hence future earnings. The optimal schooling choice amounts to identifying the optimal time for leaving school and entering the labor market such that expected total lifetime income is maximized. Restricting attention to the interior solution, the first order condition for the optimal years of schooling S is given by

$$\theta'(S) e^{\theta(S)} \int_S^R e^{-rt} p(t) dt = e^{-rS} p(S) e^{\theta(S)}. \tag{3}$$

Condition (3) is the central condition for the analysis of the role of longevity for the years of education and is analogous to condition (2) in Hazan (2009). The right hand side of condition (3) represents the expected income that is forgone by postponing the entry in the labor market at $t = S$ and not supplying labor with a return $e^{\theta(S)}$ at S. The left hand side is the gain from extending the education period and depends on the marginal increase in earnings, which pay off during the entire remaining work life. This gain is given by the marginal increase in earnings potential of $\theta'(S)e^{\theta(S)}$, which accrues over the remaining work life and is therefore multiplied by the total discounted expected lifetime labor supply associated with S years of schooling, $\int_S^R e^{-rt} p(t) dt$. Optimality requires equality between the expected discounted opportunity cost in terms of foregone earnings caused by an additional period of time invested in education, and the expected discounted returns from higher productivity over the worklife.

[1] Since the main point neither depends on the consideration of endogenous retirement, nor of hours of work and school, we abstract from these issues for the moment. Their role is discussed in Section 4.

2.3 The Role of Changes in Mortality Rates

A change in the survival probability distribution P generally affects both the marginal benefits *and* the marginal (opportunity) costs of schooling. Rearrange condition (3) as

$$\frac{1}{\theta'(S)} = \frac{\int_S^R e^{-rt} p(t) dt}{e^{-rS} p(S)} \,, \tag{4}$$

where $1/\theta'(S)$ is a measure of the (relative) marginal change in earnings in response to an increase in S. If $\theta'(S)$ is a decreasing function of S, then the left hand side is increasing in S. Hence, for a change in longevity, i.e., in the survival law P, to induce an increase in schooling S in the optimum, it must be the case that the relative benefits from schooling evaluated at S, the right hand side of (4), also increase. To facilitate exposition, denote the benefits from the expected lifetime devoted to work as $B(S|P) = \int_S^R e^{-rt} p(t) dt$ and the opportunity cost by $K(S|P) = e^{-rS} p(S)$. The magnitude $B(S|P)/K(S|P)$ is the ratio between the expected benefits and the expected costs of delaying entry in the labor market at $t = S$.

Proposition 1. *If earnings are a concave (linear) function of S, then a change in the distribution of survival probabilities P leads to an increase in S if, and only if, it is associated with an increase (no decrease) in the benefits of schooling relative to the opportunity costs,*

$$\frac{B(S|P)}{K(S|P)}. \tag{5}$$

Proposition 1 characterizes the necessary condition for an increase in schooling S, stating that, in the case of a (weakly) concave earnings function, schooling can increase in the optimum if, and only if, the benefits of delaying entry in the labor market increase *relative* to the opportunity cost, i.e., if the right hand side of (4) is increasing. The Proposition implies, in particular, that a necessary condition to observe an increase in effective schooling following a reduction in mortality rates is that the *relative* marginal benefits computed at the optimal school leaving age increase, or at least do not decrease. A corollary of this observation is that, once a generic, non-rectangular survival law is considered, an increase in expected total hours of work, given in this simple set up by $B(S|P) = \int_S^R e^{-rt} p(t) dt$, is neither a necessary nor a sufficient condition for lower mortality to induce more schooling, as was claimed in Hazan (2009).

The Role of a Rectangular Survival Probability Distribution. With a perfectly rectangular survival probability distribution, individuals survive with certainty until the age $\overline{T}$ at which they die with certainty, so that $\overline{T} = T$ and $p(t) = 1$ for all $t \leq T$ and $p(t) = 0$ for all $t > T$. This assumption implies that the right hand side of condition (4) specializes to

$$\frac{\left(1 - e^{-r(R-S)}\right)}{r} \,, \tag{6}$$

which is the right hand side of condition (5) in Hazan (2009, p. 1834). For any given interest rate r, expression (6) can increase if, and only if, $R - S$ increases. This observation leads Hazan (2009) to formulate the hypothesis that total expected lifetime hours of work $B(S|P)$ should increase in order for larger longevity to induce larger optimal schooling S. This hypothesis disregards the changes in the opportunity costs, $K(S|P)$, however.

Notice that under the assumption of a perfectly rectangular survival probability distribution, reductions in mortality can affect the lifetime earnings only by extending the maximum longevity, but not by changing the probability of surviving during working ages. In Section 3 we document that historically the main effect of mortality reductions was to increase survival during prime working ages, and not maximum expected lifetime. As a result, a change in the distribution of age specific mortality rates generally influences both the expected benefits and the opportunity costs of schooling. In order to investigate whether the more general necessary condition (5) is violated in the data one therefore needs to consider the changes in the benefits as well as in the opportunity costs.

3 Empirical Implications Revisited

The empirical analysis in Hazan (2009) is motivated by the observation of the increase in both life expectancy at age 5 and average years of schooling as displayed in Figure 1, which replicates Figure 1 in Hazan (2009, p. 1830). Hazan considers data on the survival probability distribution, labor supply and years of school for subsequent 10-year cohorts of men in the U.S. born in the period 1840-1970. The data are used to estimate the evolution of total expected hours of work, and compare them to the evolution of life expectancy and schooling attainments. As empirical counterpart of the magnitude $B(S|P)$, Hazan estimates expected total work hours, ETWH given by $B(S|P) = \int_S^R e^{-rt} p(t) L(t)\, dt$ assuming $r = 0$ and using data for labor force participation rates. Similarly, the opportunity cost at labor market entry is given by $K(S|P) = e^{-rS} p(S) L(S)$. Notice that the age specific labor supply $L(t)$ is not explicitly considered in the theory in Hazan (2009), and accordingly in the simple model in Section 2, although the empirical estimates involve their consideration. In general $B(S|P)$ and $K(S|P)$ depend on age specific labor supply $L(t)$. This can be made explicit also in the theory, as discussed in Section 4.

The results in Hazan (2009) document a substantial increase in the expected number of years in the labor market, across subsequent cohorts, see Figure 6 in Hazan (2009, p. 1846), but a sizable reduction in ETWH, see Figures 7 and 8 in Hazan (2009, p. 1847-48). Under the implicit *ceteris paribus* assumption that the mortality is the only element of the necessary condition that changed across the observed cohorts, the reduction in ETWH is interpreted by Hazan (2009) as evidence that the necessary condition for longevity to increase schooling is not satisfied empirically. In view of this, Hazan concludes that the reduction in mortality cannot account of any of the increase in educational attainment.

3.1 Changes in mortality rates and labor supply

Assuming a perfectly rectangular survival probability distribution, with $p(t) = 1$ for all $t \leq \overline{T}$ and zero otherwise, implies that increases in longevity can take place only in terms of increases in the maximum length of life. This simplifying assumption is innocuous in most theoretical studies of longevity, but not in the current context, where, as was shown above, the shape of the survival law is central for the theoretical predictions and for the effect of mortality reductions on expected labor supply.

Changes in Survival Probability Distribution and "Rectangularization". Historically, the increase in longevity is mainly the result of a progressive reduction in mortality rates for intermediate ages compared to old ages and young ages. This process, which has been labeled "rectangularization" by Fries (1980), is widely studied in the demographic literature and has been documented in all countries undergoing the demographic transition, including the U.S., see, e.g., Wilmoth and Horiuchi (1999). These patterns are evident also in Figure 2(a), which replicates Figure 2 of Hazan (2009, p. 1839) and depicts the survival curves in the U.S. conditional on having survived to age 20. Figure 2(b) plots the corresponding cumulative increase in survival probabilities at different ages compared to the cohort born in 1840. The Figures also indicate that the maximum expected lifetime hardly changed. An alternative way of documenting this is by non-linear estimates of a parametric survival function using the survival data for the different cohorts of men. These estimates demonstrate the distinct effects of changes in longevity in terms of the survival probability at all ages as compared to maximum life duration, and indicate that life expectancy at birth increased substantially from 58.32 to 70.96 across the cohorts under consideration, while maximum life duration changed relatively little from 92.1 to 95.14.[2]

The larger survival probability during working ages increases, everything else equal, the relative benefits from schooling, because it increases the expected lifetime earnings over the same

[2]The results are based on estimates of a non-linear parametric specification of the survival distribution proposed by Boucekkine, de la Croix and Licandro (2003). See the Appendix for details. Figure 9(a) presents the survival probability. Figure 9(b) depicts changes in life expectancy at birth and maximum life duration implied by these estimates.

work horizon. Figure 3(a) displays the evolution across cohorts of the expected probability of remaining in the labor market at age t, conditional on being alive and entering the labor market at age 20.[3] The probability of remaining in the labor market during prime ages (up to mid 60s) increased substantially across cohorts 1840 to 1930 so that the expected number of years in the labor market rose even when accounting for changed retirement patterns, as depicted in Figure 3(b) which replicates Figure 6 of Hazan (2009, p. 1846).[4] Notice that the increase in expected years of active work documented in Figure 3(a) implies that, interpreted literally, the magnitude (6) increases in the data.

Evolution of Labor Supply. Figure 4 depicts the evolution of average weekly work hours at age 20 and in the age ranges 20-34, 35-49 and 50-70, using the cohort data of Hazan (2009). The data document a non-flat labor supply time profile since for each cohort labor supply declines with age. The Figure also documents an acceleration in the reduction in hours of work at age 20. Starting from the cohorts of men born in 1870, weekly hours at age 20 rapidly fell by about a third. A similar pattern is evident also for hours of work at young ages 20-34 while the reduction is more uniform for labor supply at later ages.

3.2 Evolution of Relative Benefits and Costs of Schooling

The results presented in Section 3.1 imply that the assumption of a fully rectangular survival probability distribution, which is behind condition (6), is strongly counterfactual. We therefore replicate the main empirical analysis of Hazan (2009), but rather than only estimating the evolution of benefits, $B(S|P)$, we also consider the change in the opportunity costs $K(S|P)$. This way, we investigate whether the more general necessary condition for reductions in mortality to induce more schooling across cohorts of men born 1840-1930 in the U.S. was violated.

Figure 5(a) displays the labor supply weighted by the probability of remaining in the labor market (net of mortality and non-participation) for different ages for the cohorts born 1840, 1870, 1900, and 1930. These age-specific expected work hours are the raw cohort estimate data that Hazan (2009) uses to estimate $B(S|P)$ by assuming labor market entry at age $t = 20$

[3]This Figure replicates Figure 5 of Hazan (2009, p. 1845). Technically, the estimates depict the survivor function of cohort c in the labor market, which is given by

$$S_c(t|t \geq 20) = \Pi_{\tau=20}^{t} \mu_c(\tau),$$

where $\mu_c(\tau) = 1 - [d_c(\tau) + (1 - d_c)(\tau)R_c(\tau)]$ with $d_c(\tau)$ being the probability that a member of cohort c dies at age τ and $R_c(\tau)$ being the probability that a member of cohort c retires at age τ.

[4]In related work on U.S. data, Kalemli-Ozcan and Weil (2007) find that reductions in mortality may actually lead to earlier optimal retirement.

and by aggregating across all age groups $t \geq 20$, with $r = 0$. The Figure also shows the evolution of the corresponding opportunity costs $K(S|P)$, in terms of expected hours of work at labor market entry. The results are depicted in Figure 5(b), which reports the evolution of $B(S|P)$ and $K(S|P)$ across the cohorts born between 1840 and 1930 for $r = 0$. As already documented by Hazan (2009), $B(S|P)$ declines. Notice, however, that because of the reduced work intensity at labor market entry there is also a substantial decline in the opportunity cost, the denominator of condition (5). In fact, as noticed by Hazan (2009, p. 1852), the main reason for the declining trend in expected total hours of work is the reduction in hours of work at young (and old) ages, rather than at mid working ages. The relatively stronger reductions in labor supply at young ages become evident also from Figure 5(a). The observation of a more than proportional reduction in labor supply at labor market entry compared to labor supply at later ages implies that the opportunity costs may have fallen by more than the benefits, so that their ratio may have eventually increased. Figure 5(c) plots the benefits and costs, as well as their ratio $B(S|P)/K(S|P)$, normalized to the respective levels for the cohort born in 1840. The results indeed suggest that the relative benefits have not declined across cohorts. Figure 5(d), which reports the estimates of the normalized ratio $B(S|P)/K(S|P)$ for discount rates of 0, 0.05 and 0.10, documents the robustness of this finding for different discount rates. Qualitatively similar results arise when using estimates based on alternative measures of working hours or survival probability, as documented in Figures 6 and 7. Consistently, all estimates imply that there is no obvious violation of the necessary condition for lower mortality rates to have increased schooling investments once considering also the change in the opportunity cost, rather than restricting attention to the change in absolute benefits in terms of expected total work hours.

4 Discussion

Proposition 1 summarizes the observation that a change in the survival distribution leads to an increase in schooling only if it is associated to an increase in its benefits *relative* to its opportunity costs. This implication does not depend on the consideration of endogenous retirement which is taken as given when deriving the first order condition for optimal schooling and is explicitly considered in the empirical estimates. In Section 2 we have considered the very same framework studied in Hazan (2009) which neither involves the explicit consideration of labor and schooling hours, nor generic specifications of the human capital production function. The result that, with a generic survival function, it is relative, and not absolute, benefits that matter for schooling choices is unrelated to these simplifying assumptions. In general, however, relative benefits do not only depend on expected hours of work during active life and at entry in the labor market but also on the production of human capital during the last period at school. To illustrate this point, maintain the assumption of perfect capital markets and consider a lifetime budget constraint given by,

$$\int_S^R e^{-rt} p(t) L(t) \, y(h(S)) dt = \int_0^{\overline{T}} e^{-rt} p(t) c(t) \, dt. \tag{7}$$

where $L(t)$ denotes labor supply at age t, and $y(h(S))$ is the earnings per unit of labor time for $h(S)$ units of human capital acquired in S years of schooling. Also, denote by $h'(S) = g(s(S))$ the production of human capital associated with spending $s(S)$ hours at school at $t = S$. Assuming a twice differentiable and strictly concave indirect utility and restricting attention to the interior optimum, the first order condition for the optimal years of schooling S is given by,

$$y'(h(S)) g(s(S)) \int_S^R e^{-rt} p(t) L(t) \, dt = e^{-rS} p(S) L(S) \, y(h(S)). \tag{8}$$

The age specific hours of work $L(t)$ are considered as given when taking the first order condition with respect to years of schooling, S. Following Hazan (2009), the estimates of relative benefits and costs consider the actual labor supply $L(t)$ and labor force participation rates observed in the data, which are interpreted to be determined optimally (or simply taken to be exogenous). The interpretation of condition (8) is the same as that of the first order condition (3): optimal schooling requires that the marginal increase in earnings, $y'(h(S))$ associated with the marginal increase in human capital, $g(s(S))$, which accrues over the expected work life $\int_S^R e^{-rt} p(t) L(t) \, dt$, is equal to the expected loss in earnings due to postponing entry in the labor market, $e^{-rS} p(S) L(S) \, y(h(S))$. Equation (8) can be re-written as,

$$\frac{1}{y'(h(S))/y(h(S))} = g(s(S)) \frac{B(S|P)}{K(S|P)}. \tag{9}$$

where $B(S|P) = \int_S^R e^{-rt} p(t) L(t) \, dt$ and $K(S|P) = e^{-rS} p(S) L(S)$ are exactly the magnitudes empirically estimated in Section 3. Hazan (2009) assumes a linear production function of human capital $g(s(t)) = s(t)$ and that all available time is devoted to school or work $s(t) = L(t) = 1$ which implies that $g(s(S)) = 1$. Further, restricting attention to a rectangular survival probability function the right hand side of condition (9) simplifies to (6), which is condition (5) in Hazan (2009).

The concavity of the earnings function $y(\cdot)$ is sufficient to satisfy the conditions of Proposition 1.[5] Hazan (2009) considers the formulation $y(h(S)) = e^{\theta(S)}$, so that $y'(h(S))/y(h(S)) = \theta'(S)$,

[5]For any twice continuously differentiable function $y(h(t))$, with $y'(h(t)) > 0$ and $y''(h(t)) \leq 0$, the expression $y'(h(S))/y(h(S))$ in equation (9) is non-increasing in $h(S)$.

which is assumed to be a (weakly) decreasing function of S. In contrast, the literature typically considers an earnings function $y(h(S)) = w \cdot h(S)$, where w is the marginal return to a unit of human capital per unit of working time. This return is determined in competitive markets and taken as given by individuals when making optimal schooling decisions so that $y'(h(S))/y(h(S)) = 1/h(S)$. Since both $h(S)$ and $1/\theta'(S)$ are assumed to be increasing in S, the result of Proposition 1 is unaffected by the actual specification of the earnings function.

The most relevant difference between condition (5) and the right hand side of (9) is the consideration of the increase in human capital at age $t = S$, $g(s(S))$, which influences the marginal benefits of delaying school at $t = S$. The literature generally considers a production of human capital which is strictly increasing and concave in time devoted to school. For instance, Ben-Porath (1967) and Blinder and Weiss (1976) assume functions $g(\cdot)$ with $g(0) = 0$, $\partial g(\cdot)/\partial s > 0$ and $\partial^2 g(\cdot)/\partial s^2 < 0$, as well as a linear earnings function. On the contrary, Hazan (2009) considers a linear (identity) production function of human capital, $g(s(S)) = s(S)$, and a concave earnings function $y(h(S)) = e^{\theta(S)}$ (see also the discussion in footnote 10 page 1834). Note that in general the level of $g(s(S))$ is not directly observable in the data (as are θ or y). This does not preclude an investigation of whether the necessary condition is violated, however. It is well established that $s(S)$, measured in terms of hours invested in schooling before entry into the labor market, has been increasing substantially overtime. This is also illustrated in Figure 8 for the period after 1870 for which data are available from Ramey and Francis (2009). With any monotonic human capital production function, $g(\cdot)$, the observed increase in hours of schooling $s(S)$ implies an increase in the production of human capital at labor market entry, $g(s(S))$.

This discussion illustrates that once a more general specification of the human capital production function is considered, the the right hand side of (9) can have decreased *only if* the ratio $B(S|P)/K(S|P)$ has exhibited a sufficiently pronounced decline. The only qualitative difference with respect to the theoretical result of Section 2 is therefore that the observation of a reduction in $B(S|P)/K(S|P)$ is a necessary, but not sufficient, condition to detect a violation in the necessary condition for lower mortality to induce more schooling. In view of the empirical results presented in Section 3, this discussion confirms that it is not possible, a fortiori, to detect an open violation of the necessary condition in the data when considering a human capital production function with the typical properties considered in the literature.

5 Concluding Remarks

This note revisited the theoretical analysis of Hazan (2009) by relaxing a set of simplifying assumptions. The analysis has demonstrated that mortality reductions induce an increase in optimal schooling if, and only if, they increase the benefits of increased schooling *relative* to the (opportunity) costs. An increase in expected total work hours is generally not a necessary (nor a sufficient) condition for lower mortality rates to induce more schooling; it is a necessary condition only under specific but counterfactual assumptions.

Hazan (2009, page 1832) argues that the failure to meet a necessary condition is sufficient to refute a hypothesis. The replication of the empirical analysis of Hazan (2009) confirms a pronounced decline in total expected hours of work. When generalized to the explicit consideration of the opportunity costs of schooling, however, the data provide no evidence for an obvious decline in relative benefits across the cohorts of men born 1840-1930. On the contrary, the data show that the reduction in age specific mortality rates during working ages was associated with a progressive substitution from labor hours to schooling hours at young ages, with an increase in expected years in the labor market, even despite earlier retirement, and with the consequence of an increase in the relative benefits of prolonged schooling. The results presented in this note therefore do not confirm Hazan's conclusion that the necessary condition for increased longevity to have caused the increase in schooling is openly violated in the data. Rather, the evidence is consistent with the possibility that increased longevity caused the observed increase in average years of schooling for the cohorts born after 1870.

To interpret these results it is important to notice that in the absence of reliable estimates of the human capital production function and the earnings function, observing an increase in expected work hours relative to work hours at labor market entry does not allow to conclude that the reductions in mortality were indeed the causal driver behind the observed increase in schooling. Furthermore, the empirical analysis in Hazan (2009), and accordingly also the replication performed in this paper, is conducted using the observable variation in labor supply and schooling years under the implicit assumption that changes in the mortality distribution were the only relevant variation affecting optimal schooling decisions across cohorts. Over a period of the last 150 years, this is hardly a realistic assumption, since it requires assuming that, e.g., the market returns to human capital, the human capital production function and the working of credit markets have been unchanged over this period. Providing more conclusive evidence on the role of reductions in mortality for schooling will require to account more explicitly for observed and unobserved changes in other variables that are relevant for the optimal schooling decision and constitutes an interesting, but challenging, topic for future research.

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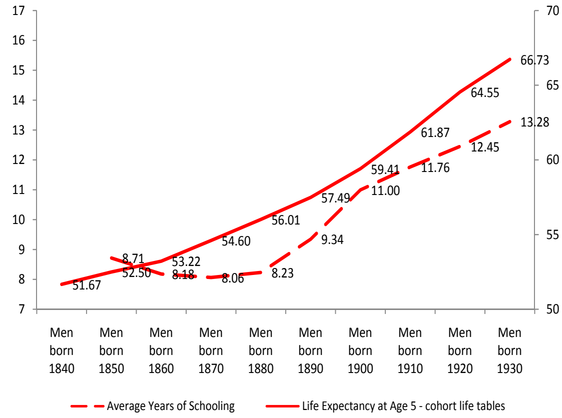
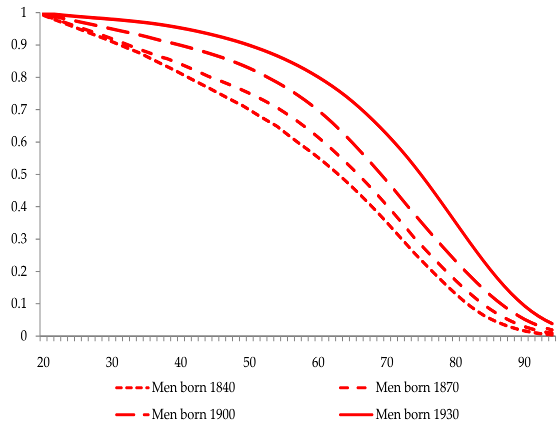
Appendix. Figures

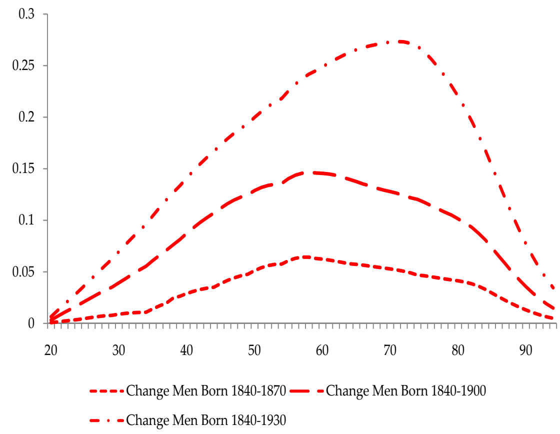


Panel (a) replicates Figure 1 in Hazan (2009). See text for details.

Figure 1: Life Expectancy and Average Years of Schooling



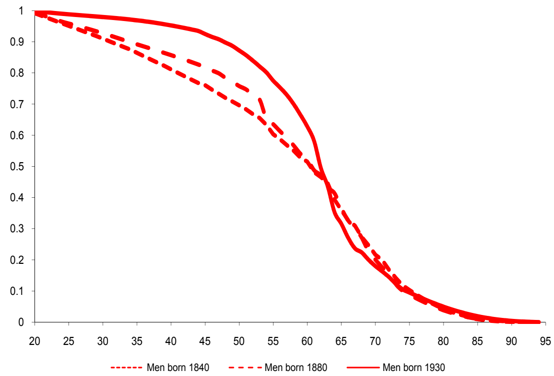
(a) Survival Probability conditional on Reaching Age 20 for Men Born in 1840, 1870, 1900, and 1930



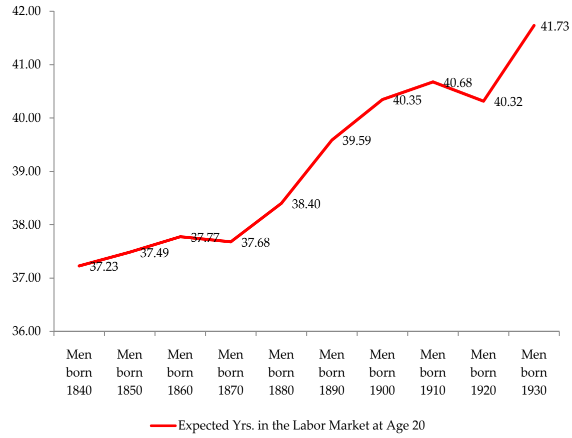
(b) Changes in Survival Probability across Cohorts by Age

Panel (a) is a replication of Figure 2 of Hazan (2009) for the four cohorts. See main text for details.

Figure 2: Rectangularization of Survival Probability and Longevity



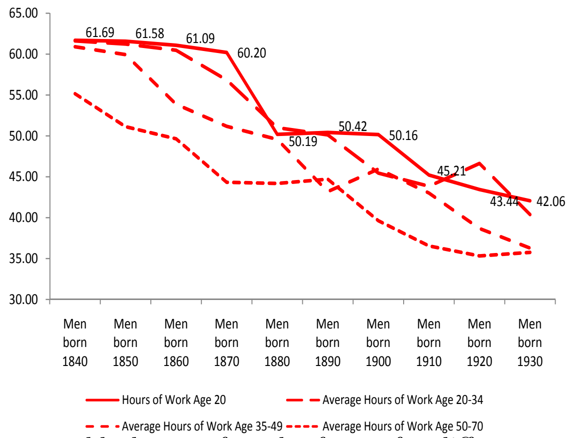
(a) Probability of Remaining in the Labor Market, Cohort Estimates for Men



(b) Expected Number of Years in the Labor Market at Age 20, Cohort Estimates for Men

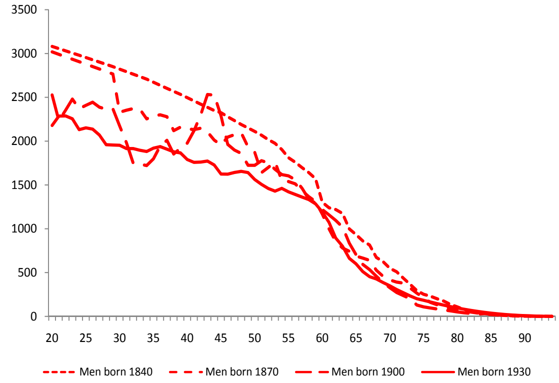
Panel (a) replicates Figure 5 of Hazan (2009). Panel (b) replicates Figure 6 of Hazan (2009) using cohort estimates. Both figures are conditional on entry into the labor force at age 20. See main text for details.

Figure 3: Changes in the Expected Work Life

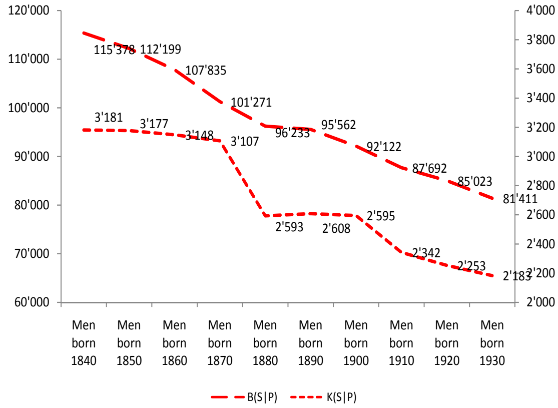


The figure depicts the average weekly hours of work of men for different ages using the cohort data of Hazan (2009).

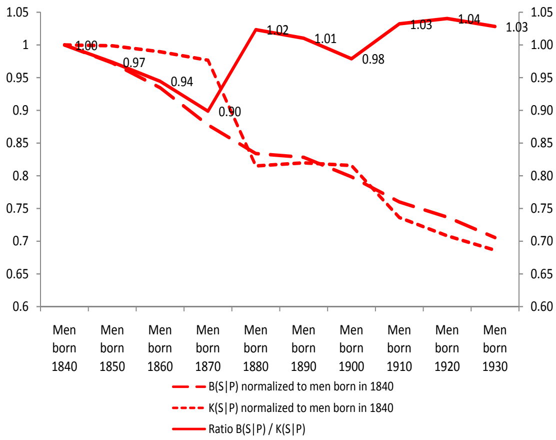
Figure 4: Evolution of Working Time



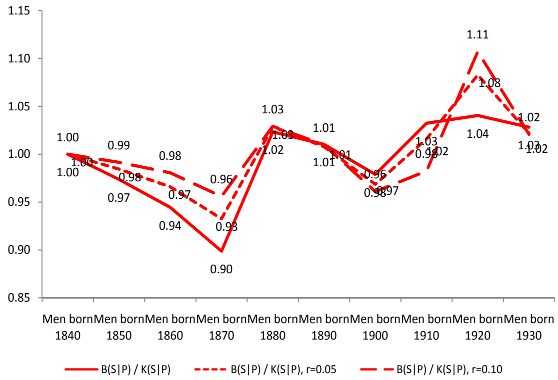
(a) Evolution of Expected Work Hours By Age



(b) Absolute Changes



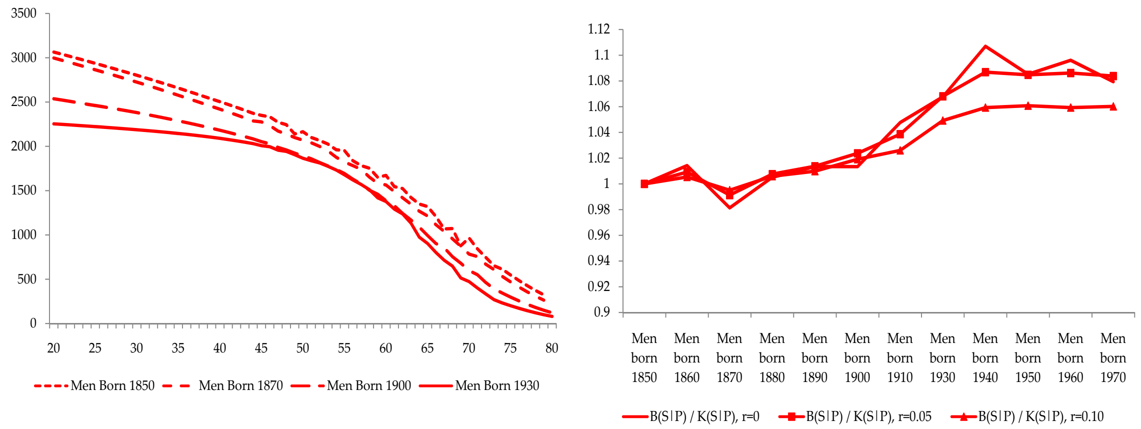
(c) Relative Changes: Normalized



(d) Relative Changes: Normalized with Discounting

Panel (a) depicts expected work hours weighted by the age-specific probability of remaining in the labor market (net of mortality and non-participation) for $r = 0$. Panel (b) depicts $B(S|P)$ for $r = 0$ which corresponds to ETWH, and $K(S|P)$ at 20 over the course of cohorts. Panel (c) depicts the same numbers as Panel (b) as well as the ratio $B(S|P)/K(S|P)$, all normalized to the level of the cohort of men born in 1840. Panel (d) shows the ratio $B(S|P)/K(S|P)$ for different discount rates: $r = 0$ (equivalent to ETWH), and $r = 0.05$ and $r = 0.10$, all normalized to the respective level of the cohort of men born in 1840. Data are cohort estimates and correspond to Figure 7 in Hazan (2009). See text.

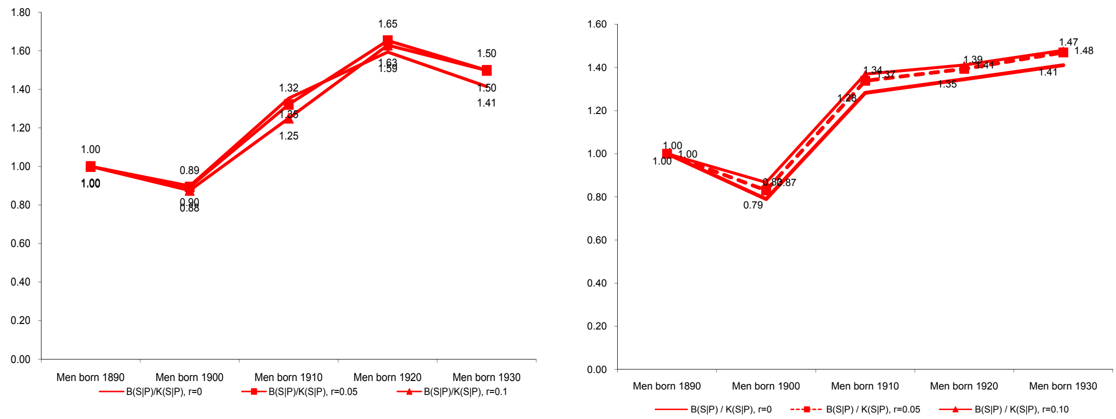
Figure 5: Relative Benefits and Costs of Schooling



(a) Evolution of Expected Work Hours (b) Relative Changes: Normalized with Discounting

Panel (a) depicts expected work hours weighted by the age-specific probability of remaining in the labor market (net of mortality and non-participation) of consecutive cohorts of men born 1850-1970 for $r = 0$. Panel (b) displays the corresponding ratio $B(S|P)/K\,(S|P)$ for different discount rates: $r = 0$ (equivalent to ETWH), and $r = 0.05$ and $r = 0.10$, all normalized to the respective level of the cohort of men born in 1850. The estimates use period estimates calculated at age 10, in correspondence to Figure 10 in Hazan (2009).

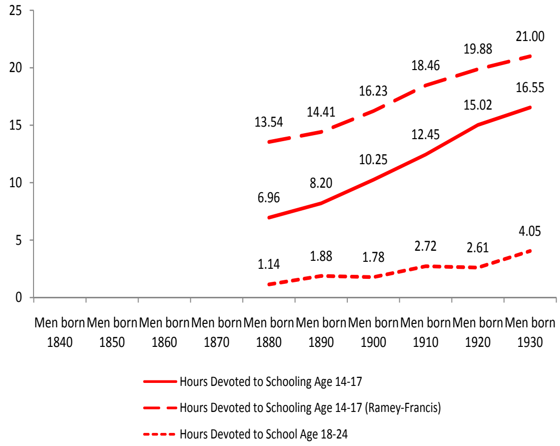
Figure 6: Relative Benefits with Different Discount Rates: Period Data Estimates



(a) Cohort Estimates (b) Period Estimates

Panel (a) displays the relative benefits of consecutive cohorts of men born 1890-1930, normalized to the value for the cohort born 1890. The data are cohort estimates, calculated at age 10, and correspond to Figure 9 in Hazan (2009). Panel (b) displays the relative benefits of consecutive cohorts of men born 1890-1930, normalized to the value for the cohort born 1890. The data are period estimates calculated at age 10, and correspond to Figure 11 in Hazan (2009). In both panels, the original hours data for the entire population are recomputed as conditional on working by accounting for school enrolment rates for ages 13-24 from the data provided by Ramey and Francis (2009). Costs and benefits are computed for school leaving age S corresponding to the average years of schooling as in Figure 5.

Figure 7: Alternative Estimates of Relative Benefits with Different Discount Rates



The figure depicts average hours in school for age groups 14-17 and 18-24 imputed for birth cohorts using the period data from Ramey and Francis (2009), excluding information on enrolment, as well as the original data by Ramey and Francis (2009). See also Figure 3A of Ramey and Francis (2009) and main text for details.

Figure 8: Evolution of Schooling Intensity

Appendix. Estimation of Survival Probability Distributions

The data provided by Hazan (2009) are used to estimate non-linearly the survival function proposed by Boucekkine, de la Croix and Licandro (2003), which takes the form

$$p(t) = \frac{\alpha - e^{\beta \cdot t}}{\alpha - 1} \tag{10}$$

with $\alpha > 1$ and $\beta > 0$. As shown by Boucekkine, de la Croix, and Licandro (2003), this survival law delivers a good fit for real world survival functions and allows for a computation of maximum expected lifetime $\overline{T}$ as

$$p(\overline{T}) = 0 \quad \Leftrightarrow \quad \overline{T} = \frac{\ln \alpha}{\beta}\,. \tag{11}$$

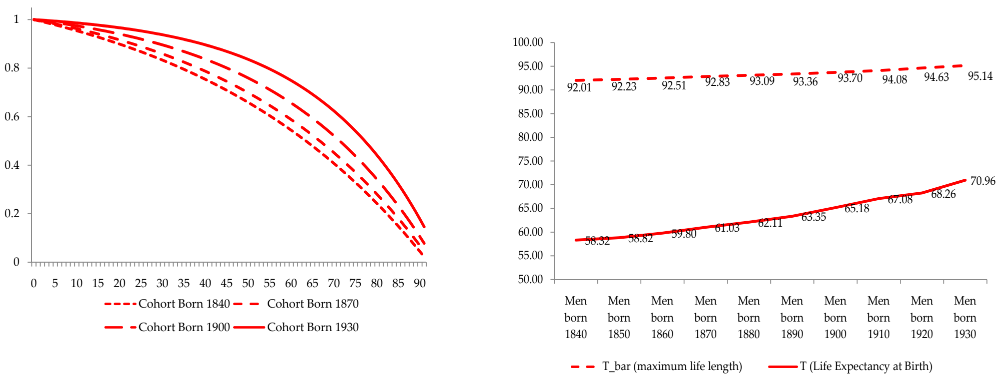
Life expectancy at birth is given by,

$$T = \frac{\alpha \ln \alpha}{\beta(\alpha - 1)} - \frac{1}{\beta}\,. \tag{12}$$

We estimate the parameters α, and β by non-linear least squares for the survival probability distribution for each cohort from 1830 up to 1930. It is worth noting that the estimates correspond quite well to the parameter estimates reported by Boucekkine, de la Croix, and Licandro (2004) for France for a comparable period.

Table 1: Parameter Estimates for a Survival Law (10)

Cohort: Men born in	1840	1850	1860	1870	1880	1890	1900	1910	1920	1930
$\hat{\alpha}$	5.37	5.66	6.39	7.49	8.64	10.28	13.46	18.05	20.94	33.42
$\hat{\beta}$	0.018	0.019	0.020	0.022	0.023	0.025	0.028	0.031	0.032	0.037
$\bar{T}$ (see (11))	92.01	92.23	92.51	92.83	93.09	93.36	93.70	94.08	94.63	95.14
T (see (12))	58.32	58.82	59.80	61.03	62.11	63.35	65.18	67.08	68.26	70.96



(a) Estimated based on (10) (b) Estimates of $\overline{T}$ and LE at age 20, T

Figure 9: Estimated Survival Probability Distribution according to (10)